CHAPTER 1
INTRODUCTION TO ROUTING IN
WIRELESS SENSOR NETWORK

This Chapter is to provide an exhaustive survey on the Energy-Efficient routing protocols for Wireless Sensor Network. A brief review of literature pertaining to the present work is also presented.

1.1 INTRODUCTION

Wireless Sensor Network (WSN) consists of a number of autonomous sensor nodes which have limited battery power and computation capabilities with sensing of various physical and environmental conditions. In recent days, WSN adequately need effective mechanisms for data forwarding to enhance the energy efficiency in network. The WSN may be used in a variety of everyday life activities or services. For example, a common application of WSN is for monitoring. In the area of monitoring, the WSN are deployed over a region in order to monitor some phenomenon. A practical use of such a network could be a military use of sensors to detect enemy intrusion. In case that the sensors detect an event like change on heat or on the blood pressure, then the event is immediately reported to the base station, which decides the appropriate action such as send a message on the internet or to a satellite. A similar area of use may be the monitoring of the air pollution, where the WSN are deployed in several cities to monitor the concentration of dangerous gases for citizens. Moreover, the WSN may be used for forest fires detection to control when a fire has started. The node will be equipped with sensors to control temperature, humidity and gases which are produced by fire in the trees or vegetation.
In addition to the above, an important area of use is the health care sector. This area the WSN may offer significant cost savings and enable new functionalities that will assist the elderly people living along in the house or people with chronic diseases on the daily activities. In wired systems, the installation of enough sensors is often limited by the cost of wiring. Previously inaccessible locations, rotating machinery, hazardous or restricted areas, and mobile assets can now be reached with wireless sensors. Moreover, the use of WSN on agriculture may benefit the industry frees the farmer from the maintenance of wiring in a difficult environment. The gravity feed water systems can be monitored using pressure transmitters to monitor water tank levels, pumps can be controlled using wireless input/output devices and water use can be measured and wirelessly transmitted back to a central control center for billing. The water industry may be benefited for power or data transmission can be monitored using industrial wireless input/output devices and sensors powered using solar panels or battery packs.

In WSN, the optimization of energy consumption is a crucial issue for real-time application. Network topology of WSN also is changed dynamically by anonymous. In WSN, energy aware routing schemes are largely utilized in various energy predicting areas including Object tracking System, Environmental, temperature monitor system and Surveillance Monitoring System. Minimize the energy consumption of sensor nodes ensure the maximum network lifetime. In order to maximization of network lifetime, it is necessary to derive an energy-efficient routing solution. Energy-efficient clustering and maximizing the network lifetime are the greatest challenge in WSN. In order to perform the WSN applications
successfully, it is necessary to design the Energy aware routing schemes that play prominent role in WSN in maximizing the network lifetime.

1.2 NEED FOR ENERGY-EFFICIENT ROUTING IN WIRELESS SENSOR NETWORK

WSN are an emerging technology of real time embedded systems for a variety of applications. Energy efficiency is one of the most important performance measures in WSN. A promising strategy for reducing energy consumption in such networks is to introduce diversity through co-operative communications technique. A co-operative communication mechanism offers considerable energy efficiency in WSN (Matamoros J & Anton-Haro C 2010) and effective co-operative communication scheme based on the optimization of QoS provisioning.

In general, WSN has great challenges in the factor of limited computation, energy, and memory resources to achieve efficient routing. Clustering techniques play a vital role in WSN to make energy efficiency in routing schemes for increasing network lifetime. Since then, a lot of work on the WSN has been carried out related to energy efficiency for a variety of applications and systems. At the same time, various energy-efficient routing protocols have been designed for WSN in order to enhance energy efficiency. Thus, each energy-efficient routing protocol may have characteristics depending on the specific application and network architecture. Classical routing protocols are not suitable for the WSN.

Cluster- based routing protocols (Sang et al 2012; Ying Liao et al 2013) are well-identified schemes that enable WSN to be highly energy-efficient. One of the limitations of wireless sensor nodes is their inherent limited energy resource. Besides maximizing the lifetime of the sensor node, it is preferable to distribute the
energy dissipated throughout the WSN in order to minimize maintenance and maximize overall system performance. Any communication protocol that involves synchronization of peer nodes incur some overhead for setting up the communication. It is very much suitable in scalability as well as efficient communication. So, it is necessary to study various energy-efficient routing algorithms. Hence, an important issue to be focused in the energy aware routing in WSN.

1.3 CHALLENGES ON ROUTING IN WIRELESS SENSOR NETWORKS

WSN have several restrictions, such as limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes. One of the main design goals of WSN is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. Many factors influence the design of routing protocols in WSN. For example, network deployment, network dynamic, data delivery model and data aggregation are major WSN system design issues and the factors that influence WSN routing design are: energy consumption, scalability and Quality of Service(QoS). Depending on the application and the size of the network, different architectures and design goals-constraints have been considered for sensor network. It is clear that the performance of a routing protocol is closely related to the architectural model.
The most important factors that influence the selection of a routing protocol are:

- **Energy Balanced Network:** When developing an energy-efficient routing protocol, the load balancing of the energy that the sensors consume should be one of the main targets of the protocol. This means that the routing protocols need to minimize the energy consumption of the network by selecting not only the shortest routes but also the routes that will lead to the extension of the network lifetime.

- **Network Dynamics:** The main components in a sensor network are the sensor nodes, sink and monitored events. In the most of the network architectures sensor nodes are assumed to be stationary. On the other hand, supporting the mobility of sinks or cluster-heads is sometimes necessary. Routing messages sent or received from nodes are more challenging since route stability becomes an important optimization factor, in addition to energy, bandwidth etc. The sensed event can be dynamic or static and this depends on the application. Thus, in a target detection application, the event is dynamic, but forest monitoring for early fire prevention is a static event.

- **Node Deployment:** This affects the performance of the routing protocol. The deployment may be deterministic or self-organizing. In deterministic situations, the sensors are placed manually and all the data are routed through pre-defined paths. In self-organizing systems, the sensor nodes are scattered randomly and create an infrastructure in an ad hoc manner.

- **Energy Considerations:** The set up of a route is greatly influenced by energy considerations. Since the transmission power of a wireless radio depends on distance squared or even higher order in the presence of obstacles, multi-hop routing
consume less energy than direct communication. However, multi-hop routing may add significant overhead for topology management and medium access control. In contrast, direct routing performs well enough if all the nodes are very close to the sink.

**Data Delivery Models:** The data delivery model to the sink, depending on the application of the sensor network, can be continuous, event-driven, query-driven and hybrid. In the continuous delivery model, each sensor sends data periodically. In event-driven and query-driven models, the transmission of data is triggered when an event occurs or a query is generated by the sink. Moreover, there are some networks that apply a hybrid model using a combination of continuous, event-driven and query driven data delivery. The routing protocol is based on the data delivery model, especially with regard to the minimization of energy consumption and route stability.

**Node Capabilities:** In a sensor network, different functionalities can be associated with the sensor nodes. In most network, a node can be dedicated to a particular special function such as relaying, sensing and aggregation, as engaging the three functionalities at the same time on a node might quickly drain the energy of that node.

**Data Aggregation/Fusion:** The sensor nodes might generate similar packets from multiple nodes that can be aggregated so that the number of transmissions would be reduced. Data aggregation is the combination of data from different sources. This can be fulfilled by using functions such as suppression, min, max and average. These functions can be performed either partially or fully in each sensor node. The computation can be less energy consuming than communication
and substantial energy savings can be obtained through data aggregation. This
technique can achieve energy efficiency and traffic optimization in a number of
routing protocols. In many network architectures all aggregation functions are
assigned to more powerful and specialized nodes. In the recent years a large number
of energy-efficient routing protocols for the WSN have been developed. However,
there is still a lot of work that has to be done, not only in the area of energy
efficiency but also, in other areas. Some factors that should be examined when
developing a routing protocol may be the following:

- **Nodes Mobility**: The nodes in the WSN were assumed to be static. In
  the last years, there is an increased interest in applications that support the mobility
  of the users. An example of this is the medical care applications where the mobile
  sensors are attached to the patients and need to send continues data from the patient
to the doctor. There are some protocols that cover this, but still there is a lot of scope
  for future research in this area.

- **Performance Evaluation on Real Environment**: The most of the
  protocols for the WSN have been evaluated through simulations. However, it is
  important to evaluate the performance of these protocols in real environments with a
  lot of users.

- **Real-Time Application and QoS**: It is an ongoing need to develop
  real-time application that will offer high level of QoS to the end users. Thus, it is
  important for the scientists to make a lot of efforts to develop routing protocols that
  will offer QoS to real-time applications.

- **Integration of Fixed with Mobile Networks**: Most of the applications,
  for example in health care monitoring, require the data collected from the sensor
nodes to be transmitted to a server so that the doctor may access and make a diagnosis or send medication to the patients. In this case the routing requirements of each environment are different, further research is necessary for handling this kind of situations.

- **QoS routing protocols**: The QoS is important in the delivery of the data in critical applications such as healthcare. Thus, the development of routing protocols that consider both energy efficiency and accurate delivery of data will help on this direction.

### 1.4 OBJECTIVES OF THE THESIS

The objective of the Thesis is to design and evaluate the following new mechanism for supporting energy-efficient routing in WSN in terms of the Gradient Routing scheme, Fuzzy logic, genetic algorithm and Multipath Routing Scheme.

- To design an Optimal Gradient Routing with On Demand Neighbourhood Information scheme to make Energy Efficiency in WSN.
- To design an Energy-efficient Routing scheme using Fuzzy logic in WSN.
- To design a Cluster based Routing Scheme based on genetic algorithm for energy efficiency in WSN.
- To design Energy-efficient Multipath Load Balancing Routing Scheme in WSN.
A brief introduction about each of them is given below.

**Optimal Gradient Routing with On Demand Neighbourhood Information Scheme:** The proposed scheme used on demand acquisitions of neighbourhood information to find the optimal routing paths that reduce the message exchange overhead. It optimizes the number of hops for packet forwarding to the sink node which gives a better solution for energy consumption and delay. The proposed protocol combines the on demand multi-hop information based multipath routing and the gradient-based network for achieving the optimal path which reduces energy consumption of sensor nodes. The proposed routing protocol provides the least deadline miss ratio, which is most suitable for real-time data delivery. The proposed Energy-Efficient Optimal Gradient-based Routing Protocol (EEOGRP) is achieved good performance with respect to the reduction in energy efficiency and deadline miss ratio. The proposed scheme utilizes minimized energy level to make routing path.

**Energy-efficient Routing Scheme using Fuzzy Logic:** The proposed protocol used novel algorithm which combined both Fuzzy Logic and Genetic Algorithm for providing an effective solution for unbalanced energy consumption problems in the WSN. The proposed protocol named as an Energy-efficient Routing protocol for WSN using Fuzzy Logic is to select an optimal cluster head by using the expected residual energy. The proposed scheme selects optimal clusters that have the highest remaining energy that making efficient route among multiple paths. Genetic approaches are implemented to form optimal clusters in WSN. It considered Distance and energy consumption metrics for developing the fitness function because making large numbers of clusters shortens the distance between the sensor member nodes.
The Genetic Algorithm optimizes the clustering schemes that extends the lifetime of the network through distributed clustering. The proposed scheme also uses an optimum fuzzy set approach to elect the cluster head based on three fuzzy descriptors namely expected energy, residual energy and centrality of cluster for making optimum decisions. The fuzzy based cluster approach consists of a setup and maintains phases. Cluster heads are elected in setup phase by using an optimum fuzzy set and then the cluster is formed by group of nodes. After the cluster heads has been elected, it broadcasts its cluster head ID for each node in the cluster. In “maintain phase”, the cluster heads collect the aggregated information and then send it to the base station. The node with most energy is selected among multiple nodes with maximum chance. The node with the maximum chance is elected as cluster head. The proposed scheme used GA and fuzzy logic for increasing network lifetime with respect to energy efficiency and Packet Delivery Ratio.

**Cluster-based Routing Scheme based on genetic algorithm:** The proposed Energy-efficient Cluster-based Routing protocol based on genetic algorithm is to construct optimal clusters and cluster heads. For dynamic topology change of WSN, convergence usually becomes a big problem that requires Genetic Algorithm is to keep a certain population diversity level to maintain their adaptability. To address this problem, the proposed scheme used the random immigrants approach to maintain the diversity level of the population through replacing some individuals of the current population with random individuals in every generation. The memory scheme applies to form optimal clusters by storing useful information from the current environment, either implicitly through redundant representations or explicitly by storing good solutions of the current population. The
stored information can be reused later in new environments. The proposed scheme can achieve energy efficiency within the minimum number of hops and also increases the network lifetime and reduces the energy consumption to improve the network performance.

**Multipath Load Balancing Routing Scheme:** A novel load balancing multipath routing scheme for WSN. It uses a load balancing mechanism to deal with energy related multipath routing issues. In the proposed scheme, the packets are forwarded across multi paths using a reliable scheme, which offers optimization alternatives. It achieved significant reliability- improvement in the multi path routing scheme at the source. It is desirable to design a reliable multipath routing scheme to provide a failure tolerant routing scheme. The proposed scheme used the path vacant ratio metric to evaluate and find a set of link disjoint paths from all available paths. A load balancing scheme can adjust the load over multi paths. The data packets are split into multiple segments that delivered through multi paths based on the path vacant ratio that make energy efficiency. The proposed scheme can achieve maximum packet delivery ratio within minimum number of hops. The proposed scheme also provides an efficient data deliver service in case of path failure through the alternate path. The outcomes obtained from this work are: end to end delay is low, maximum throughput, minimum energy consumption and minimum routing overhead.
1.5 ORGANIZATION OF THE THESIS

The Thesis is organized in seven chapters:

**Chapter 1** Introductory Part gives a brief introduction about the energy efficiency issues related to maximizing the network lifetime in WSN. The need for energy efficiency, effective routing schemes and clustering requirement in WSN has been discussed. The problem statement of existing routing and clustering schemes related to energy efficiency for WSN have been discussed. The main objective of the Thesis is explained in detail. The focused objectives are designed and evaluated as energy-efficient routing schemes in the area of Optimal Gradient Routing with On Demand Neighborhood Information, Fuzzy Logic, Genetic Algorithm and load balancing multipath routing.

**Chapter 2** ‘Literature Survey’ presents a literature review to provide necessary background for a general understanding of challenges faced while maximizing network lifetime in WSN. This Chapter presents an overview of latest literatures in the following areas. Various routing schemes and literatures related to increase the network lifetime of WSN has been reviewed. Energy-efficient Clustering mechanisms for group communication have been studied. Challenges of energy-efficient routing in WSNs are surveyed and problems related to maximizing the network lifetime are marked.

**Chapter 3** deal with “Optimal Gradient Routing with On Demand Neighbourhood Information scheme”. This scheme aims to improve the packet delivery ratio and reduce energy consumption. This Chapter explains about how Optimal Gradient Routing with On Demand Neighbourhood Information is achieved in optimal routing. The mechanisms used for combining the On demand multi-hop
information-based Multipath routing Protocol (OMLRP) and the gradient-based network is also explained. Further, it describes how to find the optimal routing paths that reduce the message exchange overhead. This scheme is energy-efficient in terms of computations and communications performed in providing energy-efficient routing for WSN. The outcomes obtained from this work are: energy efficiency and deadline miss ratio, packet delivery ratio, routing overhead and throughput.

Chapter 4 deal with “Energy-efficient Routing Scheme using Fuzzy logic”. This scheme aims to increase energy efficiency and to overcome group communication relevant issues in WSN. This Chapter explains about the formation of the optimal clusters based on fitness parameters including Cluster Distance (CD), Direct Distance to Base Station (DDBS) and Energy of nodes. Also discussed, the Fuzzy Logic approach is applied to select an optimal cluster head by using expected residual energy. Further, the proposed scheme is able to achieve minimum energy consumption by sensor nodes. The outcomes obtained from this work are: The packet delivery ratio is very high and energy consumption and routing overhead is very low.

Chapter 5 deal with “Cluster-based Routing Scheme based on genetic algorithm”. This scheme aims to increase the energy efficiency in WSN. This Chapter explains how to construct optimal clusters and cluster heads using Genetic Algorithm. Further, the pair-wise tournament selection without replacement is employed in the proposed Genetic Algorithm (GA). The following outcome has been derived in this work: high packet delivery ratio and message received ratio with maximum network lifetime, the average energy consumption and average residual energy.
Chapter 6 deal with “Energy-efficient Load Balancing Multipath Routing Scheme”. This Scheme aims to improve energy efficiency and network lifetime. A novel adaptive load balancing multipath routing scheme is explained in this Chapter. This Chapter explains about an optimal double search mechanism that provides a reliable routing path with minimum energy cost. Energy and path vacant ratio metrics are used to select the optimal path from link disjoint multipath is also discussed. The following outcome has been derived in this work: high packet delivery ratio with maximum network lifetime, minimal routing overhead and less energy consumption.

Chapter 7 “Conclusion and future work”, summarizes the outcomes of research work and outlines possible direction for future research. The first work concludes that achieved optimal routing path and reduced energy consumption of sensor nodes. In the Second Study, Energy-efficient Routing Scheme using Fuzzy Logic is explained. It selects optimal clusters that have highest remaining energy for making efficient route among multiple paths. Third Study points out Energy-efficient Cluster-based Routing Scheme based on genetic algorithm to construct optimal clusters and cluster heads. The Fourth Study discussed on an Energy-efficient multi-path Load-balancing routing scheme in WSN. Finally, these four work are compared with related schemes to various parameters such as energy-efficiency, packet delivery ratio, routing overhead and throughput. It concluded that all the four work are performed well in terms of energy-efficiency. This work shows improving network lifetime and reduce energy consumption in WSN. Future work may consider for integrating security in energy-efficient routing schemes in WSN.